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(54) Abstract Title

A data link system

(57) The system comprises a command control station 2, a network 8 of relay elements 10 and an array 4 of remote sensor units 6. The sensor units 6 and relay elements 10 are responsive to signal reception by output of an acknowledgement signal. The control station 2 routes signals either directly to sensor units 6 or to relay elements 10 or indirectly via the network 8 of relay elements in accordance with whether or not an acknowledgement signal is generated thereby. The control station (2), the relay elements (10) and the sensor units (6) incorporate a transceiver (12,38,142 Figs 2-4 not shown) and a data processing unit (14,42,140). A similar configuration of data processing unit (14,42,140) is used in the control station (2), in the relay elements (10) and in the sensor units (6); the data processing unit (14,42,140 Fig 5 not shown) incorporates a power controller (26,126,226), a clock (34,134,234), a digital processor (30,130,230) a modem (28,128,228) and an interface multiplexer (36,136,236). The system may be used to control traffic lights, for personnel communication in hazardous situations such as fires, on pilotless aircraft for surveillance or, using sonar, for communication under water for oil exploration or production.

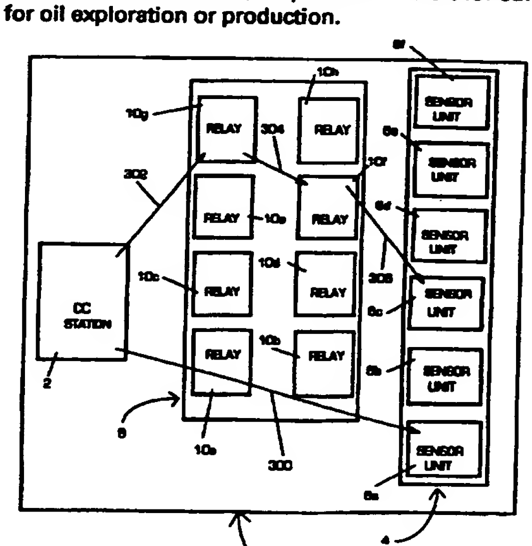
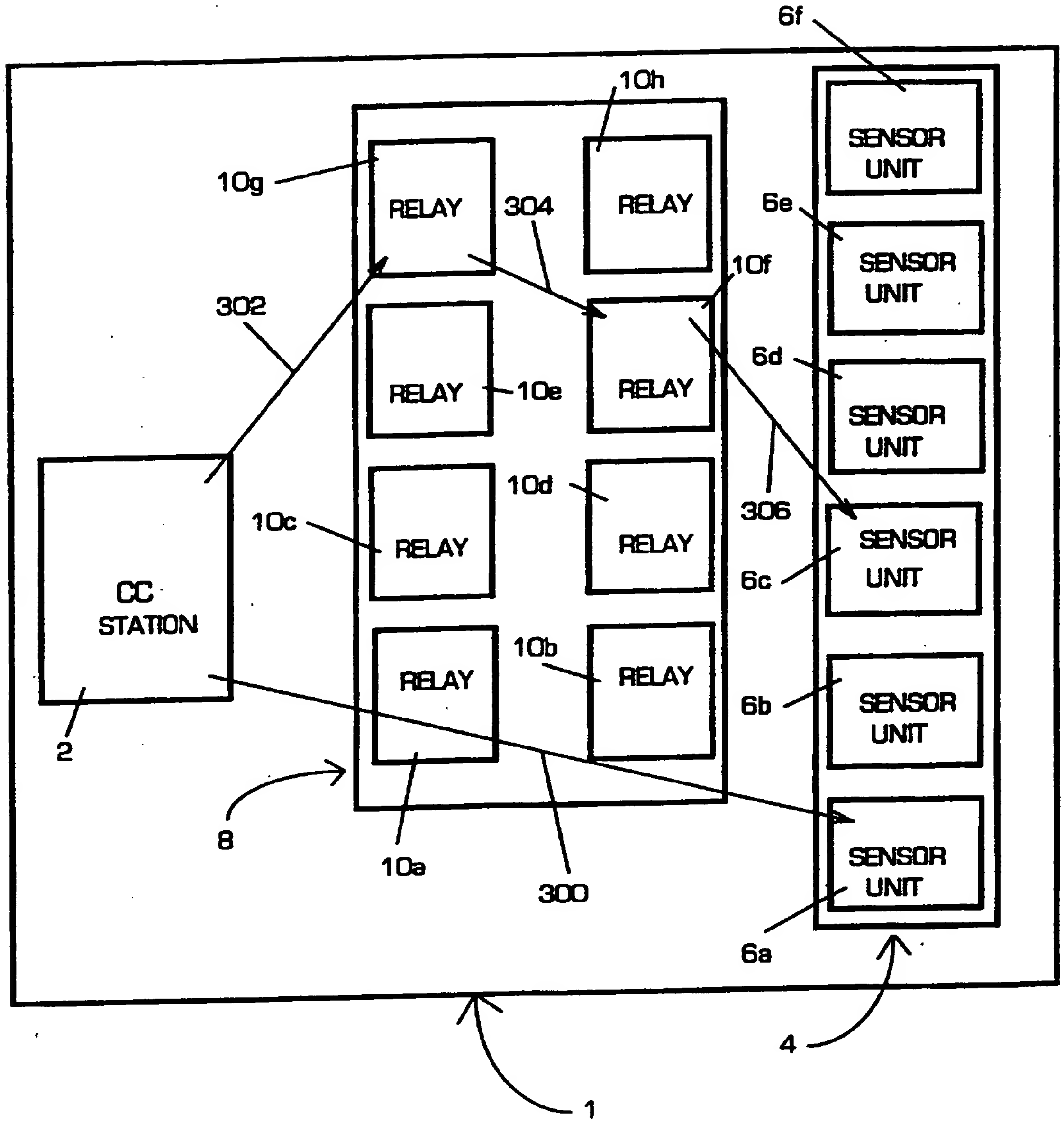


FIGURE 1

GB 2 327 019 A



6f
10h
10g
RELAY
304
RELAY
6e
SENSOR UNIT
SENSOR UNIT
10f
302
6d
RELAY
10e
RELAY
SENSOR UNIT
10d
306
10c
RELAY
RELAY
SENSOR UNIT
CC STATION
6c
10b
RELAY
RELAY
6b
SENSOR UNIT
2
8
SENSOR UNIT
10a
300
6a
4
1

FIGURE 1

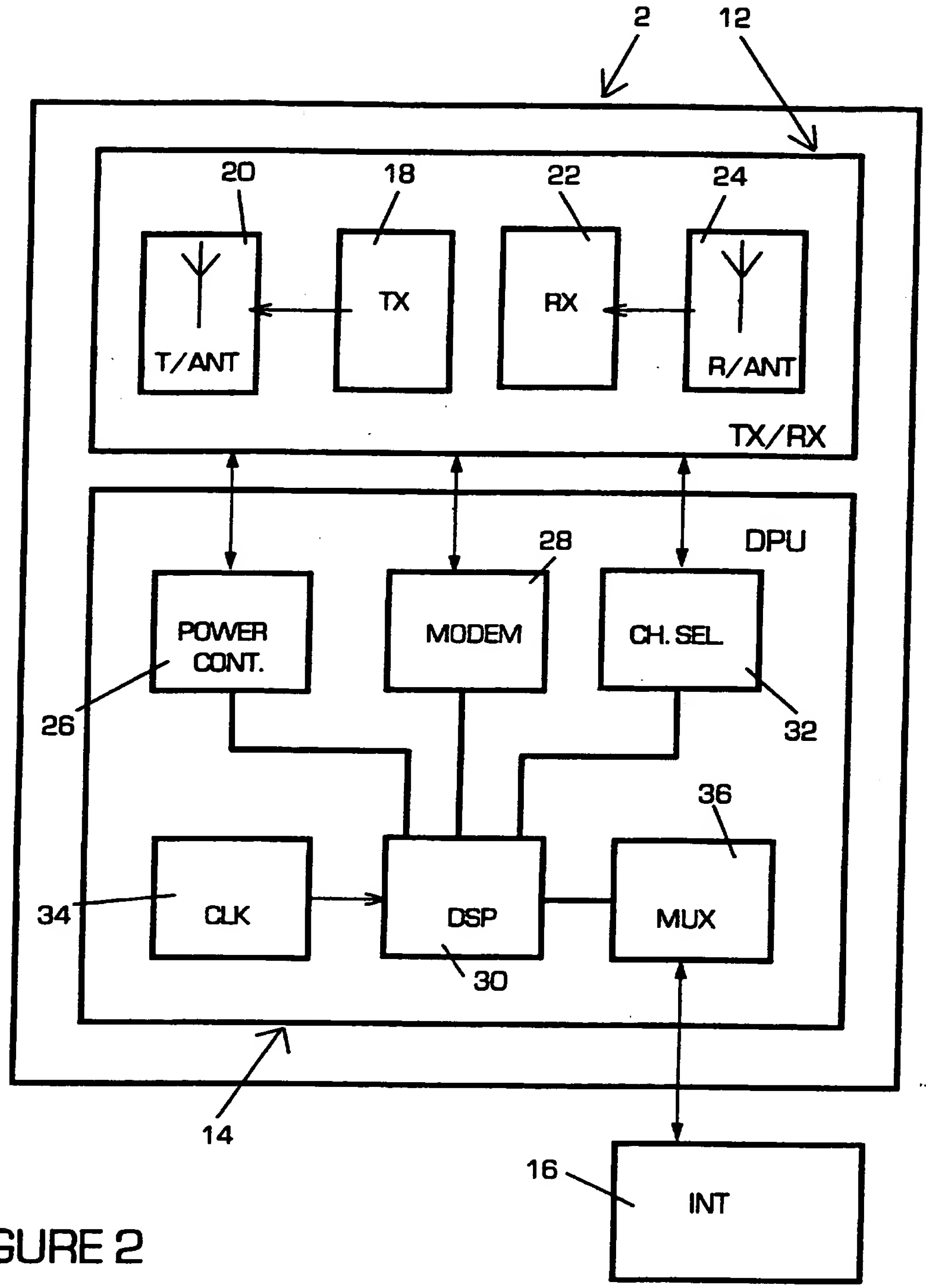

2
12
20
18
22
24
TX
RX
T/ANT
R/ANT
TX/RX
28
DPU
POWER CONT.
MODEM
CH. SEL.
26
32
36
CLK
DSP
MUX
34
30
14
16
INT

FIGURE 2

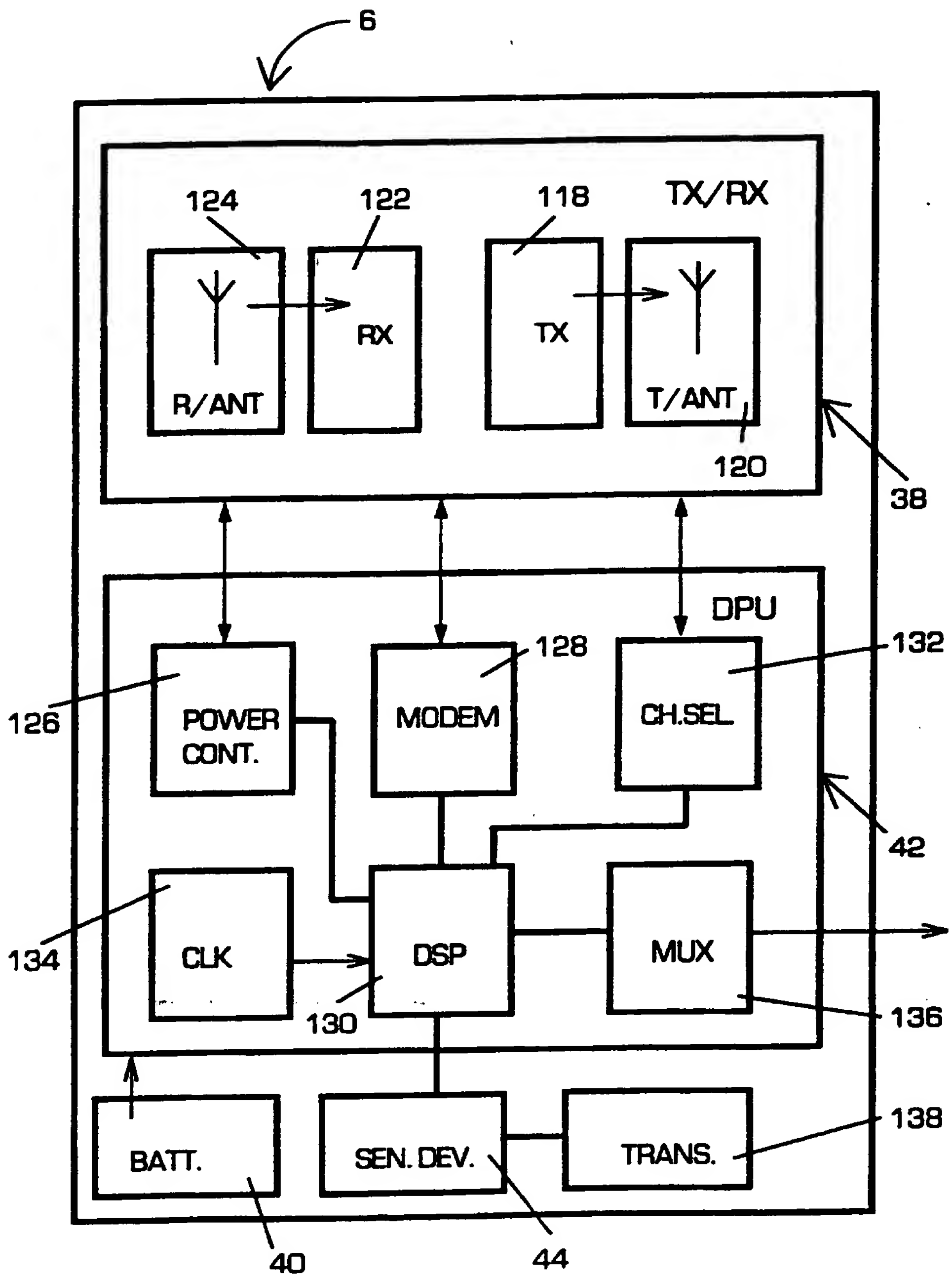

6
124
122
118
TX/RX
R/ANT
RX
TX
T/ANT
120
38
DPU
126
POWER CONT.
128
MODEM
CH.SEL.
132
42
134
CLK
DSP
130
MUX
136
BATT.
SEN. DEV.
TRANS.
138
40
44

FIGURE 3

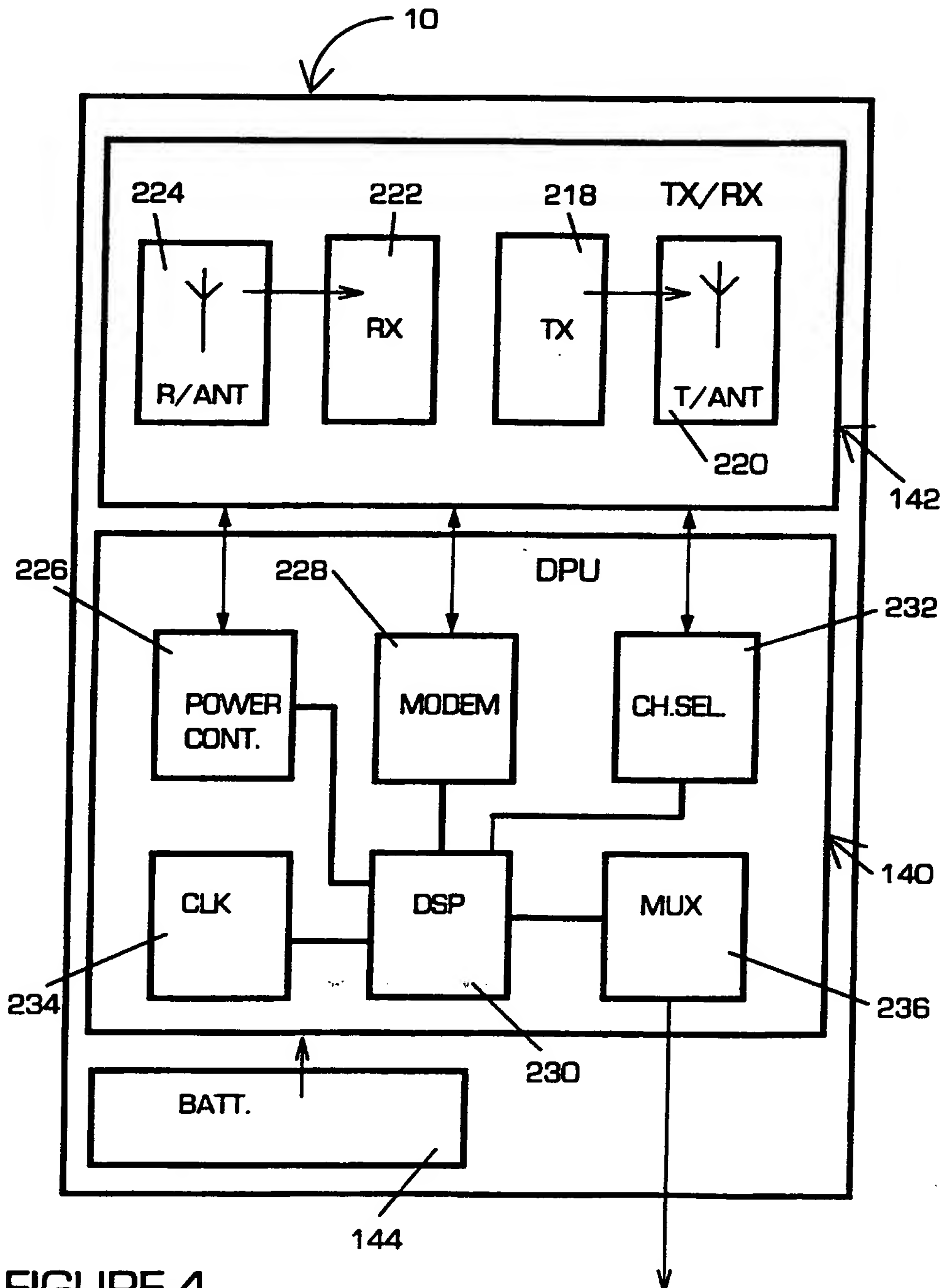

10
224
222
218
TX/RX
R/ANT
RX
TX
T/ANT
220
142
226
228
DPU
232
POWER CONT.
MODEM
CH.SEL.
CLK
DSP
MUX
140
234
236
230
BATT.
144

FIGURE 4

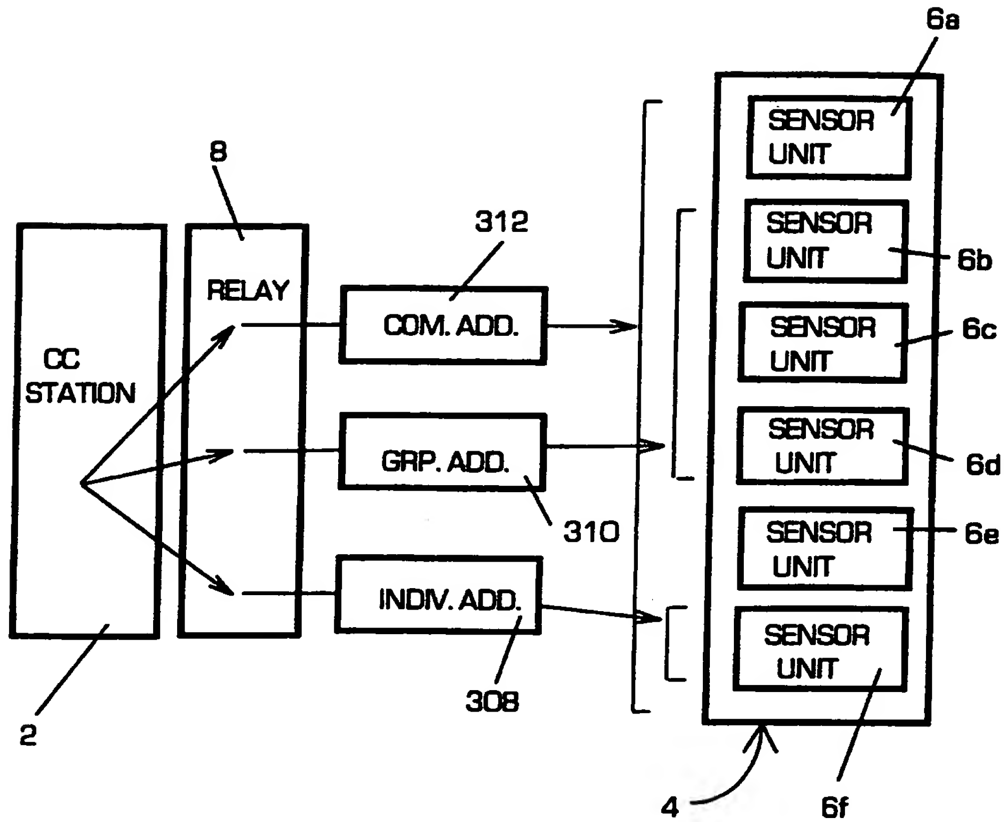

6a
SENSOR UNIT
8
312
SENSOR UNIT
6b
RELAY
COM. ADD.
SENSOR UNIT
6c
CC STATION
GRP. ADD.
SENSOR UNIT
6d
310
SENSOR UNIT
6e
INDIV. ADD.
SENSOR UNIT
308
2
4
6f

FIGURE 5

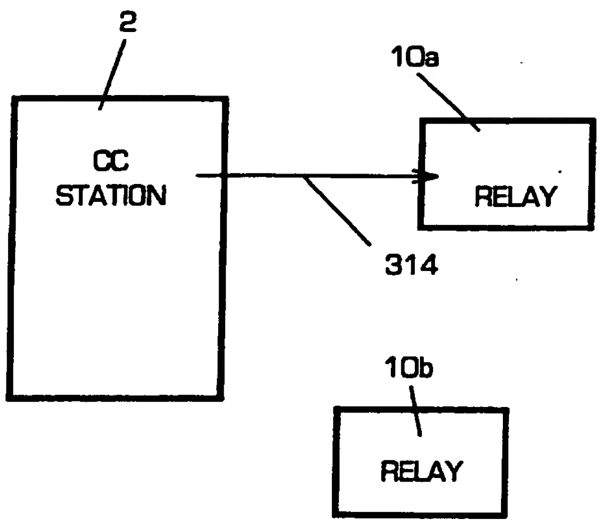


FIGURE 6

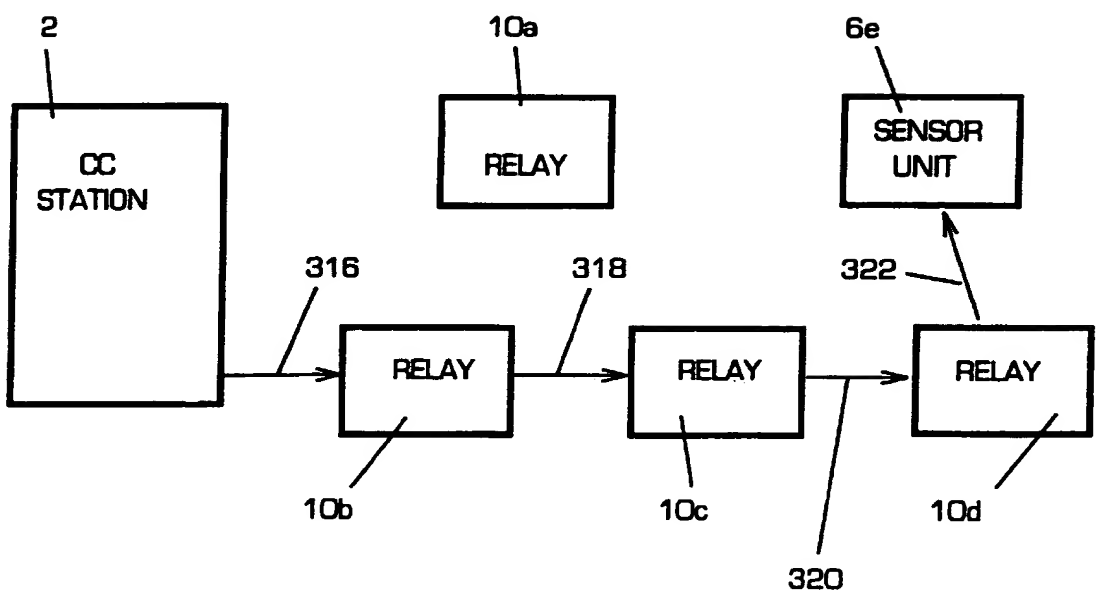
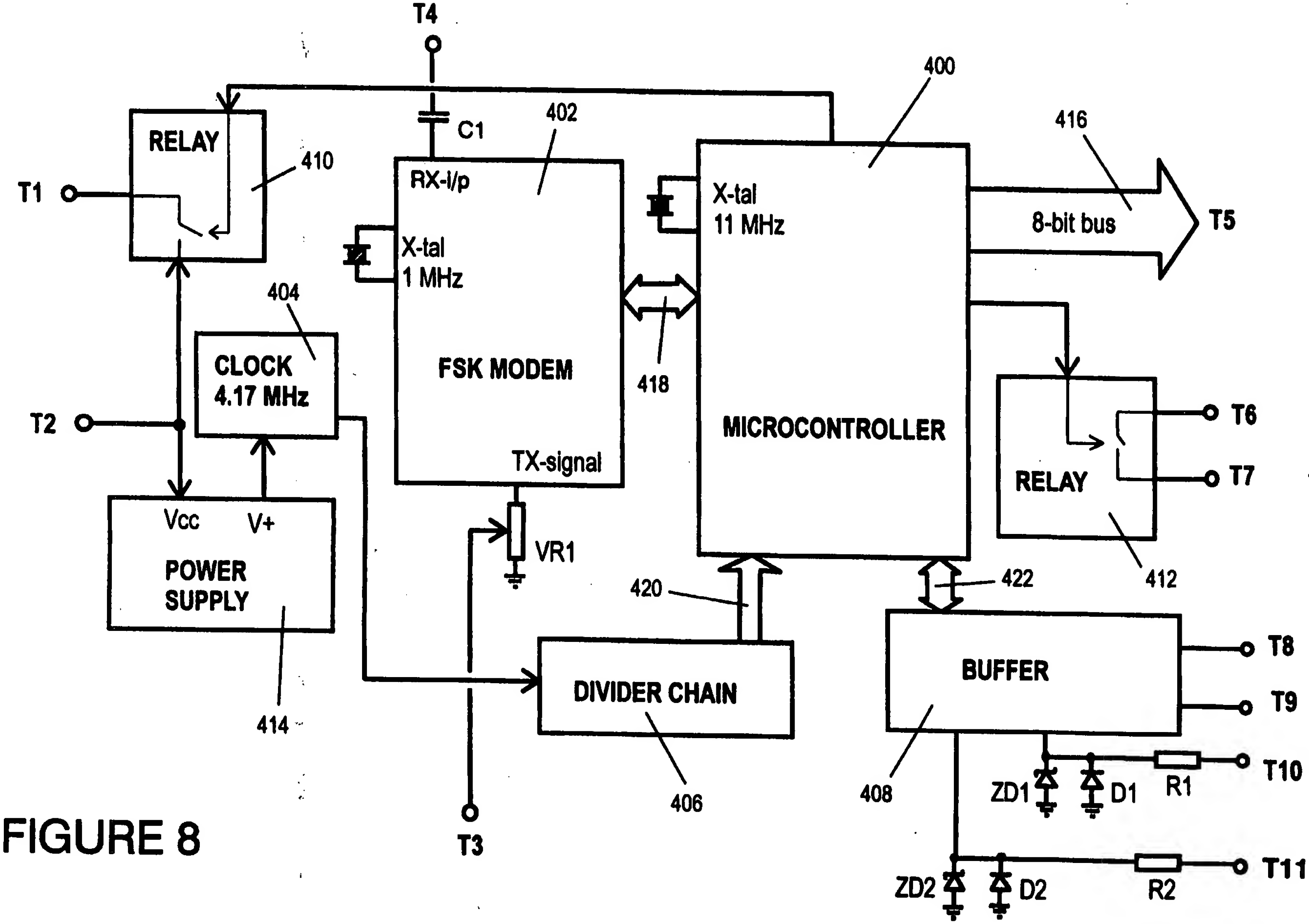


FIGURE 7

7/7



T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
RELAY
410
C1
402
RX-i/p
X-tal
1 MHz
FSK MODEM
TX-signal
VR1
404
CLOCK
4.17 MHz
Vcc
V+
POWER
SUPPLY
414
418
400
X-tal
11 MHz
MICROCONTROLLER
416
8-bit bus
RELAY
412
420
422
DIVIDER CHAIN
406
BUFFER
408
ZD1
D1
R1
ZD2
D2
R2

FIGURE 8

2327019

A DATA LINK SYSTEM

This invention relates to a data link system.

Radio links are employed in a data link system for communicating between a control station and remote devices where it is undesirable or inconvenient to employ electrical cables or fibre optic links. One of the prime requirements is that remote devices should function reliably when subjected to various forms of communication interference. In conventional systems, the effect of communication interference may be minimised by the use of frequency diversity and suitably powerful transmitters. However, transmitter power requirements to overcome interference may become prohibitive for long communication paths or where there are multiple sources of interference which are spatially distributed between the control station and the remote devices.

Wide area communication networks form part of the state of the art; a packet switched network is an example of a wide area network. In a packet switched network, each element of the network maintains a running record of its connectivity with other elements. Although this type of network is extremely powerful, it has the disadvantage of high power consumption because house keeping information flows constantly within it in an attempt to maintain element connectivity and to disguise the time at which security sensitive information is being communicated. A further disadvantage is that each remote device connected to the network has to have full packet switched capability, unless a second type of data link system is employed to connect the elements to the remote devices.

It is an object of the invention to provide an alternative form of communication system for controlling and monitoring remote devices.

The present invention provides a data link system comprising transmitting means, relaying means and receiving means responsive to signal reception by output of an acknowledgement signal, the transmitting means being arranged to route signals

either directly to the receiving means or indirectly thereto via the relaying means in accordance with whether or not an acknowledgement signal is generated thereby.

The invention provides the advantage that it provides alternative communication paths in the event of breakdown in communication due to radio shadows, sources of interference and defective parts of the relaying means.

The relaying means preferably comprises a plurality of relay elements distributed to provide multiple communications paths between the transmitting means and the receiving means.

Communication paths may be selected in the data link system for distributing signal flow to avoid concentrations of flow within certain parts of the system. Moreover, the receiving means may be arranged to output an acknowledgement signal at a predetermined time after receiving a message signal in order to avoid multiple acknowledgement signals flowing within the system and conflicting with one another.

In a preferred embodiment, the transmitting means, the relaying means and the receiving means incorporate transceiving means of like construction. The data link system is preferably operative in burst mode to reduce power requirement; to implement this, the transmitting means, the relaying means and the receiving means include transceiving means arranged to be active only when data flow is required.

The data link system may be deployed in safety critical applications for which return data flow from remote devices back to the transmitting means must be reliably achieved. Reliability of data flow may be increased by employing a network of relay elements each capable of seeking multiple signal propagation routes through the system until an acknowledgement signal is generated. In such a system, the remote devices may be arranged to output an acknowledgement signal at a predetermined time after signal reception in order to avoid conflict between acknowledgement signals propagating simultaneously.

The data link system may relay signals in an encrypted form and provide error correction at the relay elements. The relay elements, the receiving means and the transmitting means may each have power control means, frequency shift keying demodulator-modulator means, communication frequency selector means, a clock, digital processing means and interface multiplexing means.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1	is a general schematic drawing of a data link system of the invention;
Figure 2	is a more detailed block diagram of a command control station of the data link system in Figure 1;
Figure 3	is a more detailed block diagram of a remote sensor unit of the data link system in Figure 1;
Figure 4	is a more detailed block diagram of a relay element of the data link system in Figure 1;
Figure 5	illustrates a variety of different possible addressing modes for the data link system in Figure 1;
Figures 6 and 7	illustrate a signal routing operation; and
Figure 8	is a circuit diagram of a data processing unit.

Referring to Figure 1, a radio data-link system is indicated generally by 1. The system 1 comprises a command control (CC) station transmitter 2, a receiver 4 consisting of an array of six remote sensor units 6a to 6f, and a network 8 of eight relay elements

10a to 10h. The network 8 is for providing a link between transmitter 2 and receiver 4.

Figure 2 illustrates the control station 2 in more detail. It comprises a transceiver (TX/RX) unit 12, a data processing unit (DPU) 14 and an interface unit (INT) 16. The transceiver unit 12 comprises a transmitter (TX) 18, a transmitter antenna (T/ANT) 20, a receiver (RX) 22 and a receiver antenna (R/ANT) 24. The transceiver unit 12 is a frequency-programmable high-frequency transceiver type BCC39B manufactured by Racal Ltd. It may alternatively be a "Clansman" radio transceiver manufactured by Marconi Ltd and Plessey Ltd; the Clansman transceiver is a single-side-band high-frequency unit operating in the 2-88 MHz frequency range to 15 kHz frequency resolution, providing 10 Watts transmission power, providing 6 dB reception signal to noise ratio for 0.5 μV receiver sensitivity, and incorporating an integral antenna which supports both transmission and reception of radio waves from and to the control station 2 respectively.

The data processing unit 14 comprises a power controller 26, a modem 28, a digital processor (DSP) 30, a radio channel selector (CH.SEL) 32, a high stability clock (CLK) 34 and a RS232 multiplexer (MUX) 36. The processor 30 is a proprietary microcontroller device, having a reference number H87C51, manufactured by Intel Corporation. The modem 28 contains a FX409 fast-frequency binary frequency shift keying (FSK) modulator, capable of converting FSK signal tones into digital signals and vice versa and capable of operating at 1200 Baud. It does not exhibit phase discontinuities and hence provides low-amplitude spectral side-lobes in the message signal conveyed by the transceiver 12. The clock 34 contains a 4.096 MHz temperature-compensated Quartz crystal oscillator with a frequency drift of 0.5 p.p.m., corresponding to 1.5 seconds/month stability error. The interface unit 16 is a proprietary "Husky" terminal which is a robust video display unit terminal utilising a RS232 interface format. The interface unit 16 incorporates a keyboard for manual entry of data into the data processing unit 14. The interface unit 16 is connectable to the control station 2 for this purpose; alternatively, data may be entered via the RS232 multiplexer 36 which is connectable to an external computer system (not shown) for controlling the control station 2.

Referring now also to Figure 3, the sensor unit 6 comprises a transceiver (TX/RX) 38, an internal power source (BATT) 40, a data processing unit (DPU) 42 and a sensor device (SEN. DEV.) 44. The transceiver unit 38 is of identical design to the transceiver unit 12 of the control station 2 and comprises a transmitter (TX) 118, a transmitter antenna (T/ANT) 120, a receiver (RX) 122 and a receiver antenna (R/ANT) 124. The transceiver 38 is a proprietary radio transceiver capable of operating at very high frequencies (VHF) in the range of 20-90 MHz. The data processing unit 42 is of identical design to the data processing unit 14 and comprises a power controller 126, a modem 128, a digital processor (DSP) 130, a radio channel selector (CH. SEL.) 132, a clock (CLK) 134 and a RS232 multiplexer (MUX) 136. The sensor device 44 comprises an electronic circuit for conditioning signals to and from a transducer 138 which is for transducing environmental parameters such as temperature, movement, gas composition and radiation in a region surrounding the transducer 138. The internal power source 40, namely the rechargeable battery pack associated with the Clansman transceiver as described earlier, is capable of providing power for the sensor unit 6 when deployed in remote terrain or a non-stationary locality, such as a moving vehicle, where a mains electricity supply is not available or is not practical to use.

A relay element 10 is illustrated in Figure 4. The relay element 10 comprises a computer data processing unit (DPU) 140, a transceiver unit (TX/RX) 142 and an internal power source (BATT) 144. The transceiver unit 142 comprises a transmitter (TX) 218 connected to a transmitter antenna (T/ANT) 220, and a receiver (RX) 222 connected to a receiver antenna (R/ANT) 224. The transceiver unit 142 is a proprietary item, namely the Clansman radio transceiver as described previously. The data processing unit (DPU) 140 is identical to the data processing units 14 and 42; it comprises a power controller 226, a modem 228, a clock (CLK) 234, a radio channel selector (CH.SEL.) 232 and a RS232 multiplexer (MUX) 236. The multiplexer 236 is included for local data entry, programming, and testing purposes using a hand-held video display unit.

Referring to Figure 1, a direct communication path 300 extends from the control station 2 to the sensor unit 6a. Furthermore, an indirect communication route comprising paths 302, 304, 306 extends from the control station 2 to the sensor unit 6c via the relay elements 10f and 10g forming part of the network 8. More details of the communication paths 300, 302, 304, 306 will be given later.

Referring now to Figure 5, signal paths corresponding to data flow are represented by arrows from the control station 2 to selected sensor units 6. Each signal contains address information which determines which sensor unit 6 or relay element 10 will receive and act upon the signal sent. The address may be an individual sensor address as in INDIV.ADD. 308 for the sensor unit 6f. Alternatively, the address may be that of a group of sensor units 6b-6d as in GRP.ADD. 310, or as in COM.ADD. 312 for all the sensor units 6a-6f. A group of sensor units to which GRP.ADD. 310 pertains is reconfigurable by radio control from the control station 2, or by local data entry through the multiplexer 136, 236 contained within each relay element or sensor unit 6.

Figure 6 illustrates data flow along a message transfer path 314 to the relay element 10a in the data-link system 1. Figure 7 illustrates data flow along an indirect signal propagation route 316, 318, 320, 322 from the control station 2 via the relay elements 10b, 10c, 10d to a sensor unit 6e.

Figure 8 is a circuit diagram of a data processing unit as shown diagramatically as 14 in Figure 2, as 42 in Figure 3, and as 140 in Figure 4. In Figure 8, a terminal T1 is for providing power for the transceiver 12, 38, 142 (not shown). A terminal T2 is for inputting power to the data processing unit from a power source 40, 144 to the data processing unit; the power source is nominally 24 volts d.c. An audio output signal terminal T3 is for audio output from the data processing unit to an audio transmit terminal (not shown) on the transceiver 12, 38, 142. An audio input terminal T4 is for audio input to the data processing unit from an audio receive terminal (not shown) on the transceiver 12, 38, 142. A terminal T5 is an 8-bit data bus from the data processing unit for connection to channel select and digital input/output control

terminals (not shown) of the transceiver 12, 38, 142. Transmit power control terminals T6,T7 of the data processing unit are for connection to the transmit control terminals (not shown) of the transceiver 12, 38, 142. RS232 output terminals T8, T9 and RS232 input terminals T10, T11 of the data processing unit are for connection to peripheral devices (not shown) such as the interface 16.

The circuit shown in Figure 8 comprises a microcontroller 400, an FSK modem 402, a clock oscillator 404, a frequency dividing chain 406, a RS232 interface buffer 408, two transceiver power control relays 410 and 412, and a power regulation circuit 414. The microcontroller 400, having an 11 MHz crystal resonator for determining its internal digital clocking rate, has a reference number 87C51 and is manufactured by Intel Corporation. The FSK modem 402 is an integrated circuit, having a 1 MHz crystal resonator for determining its internal digital clocking rate, capable of supporting communication at a data rate of 1200 Baud. The clock oscillator 404 is a hybrid integrated circuit comprising a 4.17 MHz quartz resonator oscillator and has a reference number TCXO-8500. The frequency dividing chain 406 comprises 74HCT440 and 74HCT390 integrated circuits. The RS232 interface buffer 408 comprises a 74HCT240 integrated circuit; associated with it are input-signal limiting components R1, R2, D1, D2, ZD1, ZD2. The power regulation circuit 414 comprises 1205 and 2951CP integrated circuits; regulated outputs from the power regulation circuit 414 are connected to the clock oscillator 402 (as shown) and also as +5 volt connections (not shown) to the FSK modem 402, the divider chain 406, the microcontroller 400 and the buffer 408. An a.c. coupling capacitor C1 is connected between the FSK modem 402 and the terminal T4. A variable potentiometer VR1 is connected between the terminal T3 and the FSK modem 402.

The terminal T1 is connected to a switch contact terminal of the relay 410. The terminal T2 is connected to the power supply circuit 414 (Vcc) and also to another switch contact terminal of the relay 410. The terminal T5 comprises an 8-bit data bus 416 which is connected to port connections P00 to P07 of the microcontroller 400. The terminals T6 and T7 are connected to switch contacts of the relay 412. The microcontroller 400 has an output connection P29 which is connected to a control connection on the relay 410 and also an output connection P25 which, in turn, is

connected to a control connection on the relay 412. A data bus 418 is connected between connections P12 to P17 on the microcontroller and several connections on the FSK modem 402, namely RX synchronisation, TX input, RX output, FSK clock, RX enable and TX enable. An output signal CK O/P from the clock oscillator 404 is connected to an input CK I/P of the divider chain 406. Multiple outputs 420 (DCK O/P) from the divider chain 406 are connected to connections P11, P26, and INT1 of the microcontroller 400. The microcontroller 400 has connections 422, namely P20, P24, RXD, TXD, which are connected to connections 1A1, 2A4, 2B, 1Y2, 2Y3 on the buffer 408. The terminals T8 and T9 are connected to connections 1Y1 and 2Y4 of the buffer respectively. The terminals T10 and T11 are connected via signal limiting circuits comprising R1, D1, ZD1 and R2, D2, ZD2 respectively to input connections 2A3 and 1A2 respectively of the buffer 408.

The mode of operation of the system 1 will now be described. The control station 2, the array of sensor units 6 and the network 8 of relay elements 10 are distributed in a terrain in which localised sensing is to be performed by the sensor units 6 under supervision from the control station 2. The sensor units 6 may be located at distances as large as 40 km from the control station 2. The network 8 may be situated spatially between the control station 2 and the array of sensor units 6, or the relay elements 10 may be interspersed amongst the sensor units 6 depending upon factors such as the topography of the terrain, or the presence of metallic structures absorbing or scattering radiowave radiation, or the presence of other sources (not shown) of unwanted radio interference in the terrain. The relay elements 10 and the sensor units 6 are distributed across the terrain so that the distance between neighbouring sensor units and relay elements is in the order of 10 km or less for ensuring satisfactory radio communication between neighbouring sensor units and relay elements which employ the proprietary transceivers described previously.

The system 1 supports radio communication between the control station 2 and preferred sensor units 6, or between the control station 2 and preferred relay elements 10. A message sent from the control station 2 can either be communicated to a sensor unit directly (as in the case of communication path 300 to sensor unit 6a in Figure 1) or indirectly via the relay elements (as in the case of

communication paths 302,304,306 through relay elements 10f and 10g to the sensor unit 6c in Figure 1). The choice of whether to communicate directly with the sensor units 6 or, alternatively, indirectly via the network 8 is governed by the circumstances of the deployment of the sensor units 6 and the control station 2, particularly with regard to any radio shadows created by uneven terrain or any interference in the vicinity of the sensor units 6.

The command control station 2 attempts to communicate directly with the remote units 6. This attempt will succeed if the transmitter 18 is sufficiently powerful, the transmitter antenna 20 has sufficient gain, the antenna 124 of the sensor units has sufficient gain and the receiver 122 of the sensor units has sufficient sensitivity to make communication possible. Factors such as radio-wave propagation distance from the command control station 2 to the sensor units 6, radio shadows and local interference may prevent direct communication between the command control station 2 and the sensor units 6.

When the control station 2 sends a message directly to a sensor unit 6, it requires confirmation that the sensor unit 6 addressed has received and interpreted the message; this confirmation is provided by the relevant sensor unit 6 transmitting an acknowledgement signal radio signal, referred to hereinafter as an echo back signal. This signal takes the form of a radio transmission of 2 seconds duration at a specific radio frequency in the range 20-90 MHz. If the message sent directly from the control station 2 is addressed to more than one sensor unit (as in addressing modes 310, 312 in Figure 5), the sensor units addressed transmit their echo back signals in a predetermined sequence in order to avoid a plurality of echo back signals being transmitted simultaneously; the high stability clock 134 contained within each of the sensor units 6 ensures that the timing of the predetermined echo back radio transmission sequence is accurately maintained.

If direct communication from the control station 2 to the sensor units 6 is not feasible (for example, in a situation where an echo back radio transmission is not received at the control station 2), the station 2 has an alternative option to send a message via the network 8 to communicate with the sensor units 6. Furthermore, when

undetectable operation of the system 1 is desired, direct communication with a sensor unit 6 is intentionally avoided and a message is sent preferentially only via the network 8.

Messages are passed via the relay elements 10 in two possible ways, namely either via a network path which has been predetermined at a message source (the message source being any of the control station 2, a sensor unit 6 or a relay element 10), or via a network path which is determined by the network 8 itself. In both cases, information relating to the locations within the terrain of the relay elements 10 (and hence interconnectivity of the network 8), the location of the control station 2 and the locations of the sensor units 6 has to be available within the system 1. Such interconnectivity information can either be pre-programmed into the system 1 prior to its deployment, or determined by the system 1 itself once it has been deployed (e.g. by sending a route testing message through the network 8 as will be explained later); the location of the sensor units 6 and the relay elements 10 can be input to the data processing unit 42, 140 at each location either by inputting data through the RS232 multiplexer module 136, 236 or through radio communication from the control station 2.

A message to be conveyed through the network 8 is relayed by one or more relay elements 10 depending upon the distance to be traversed by the message and the number of relay elements 10 or sensor units 6 which are intended to receive the message. In the system 1, there are three types of message which are conveyed by the network 8, namely:

(1) data and configuration messages destined either for a relay element 10 or sensor unit 6 or both, or for the control station 2;

(2) report messages which serve an identical function to an echo back radio transmission to confirm the receipt of a message at a sensor unit 6 or a relay element 10;

(3) route test messages which are sent around the network 8 to establish the integrity and interconnectivity of the network 8 and sensor units 6.

A message to be transmitted along a predetermined route in the network 8 contains the addresses of the relay elements 10 which are required to convey the message as well as time and validation data together with the message data. The transmission of a message along a predetermined path will now be described with reference to a specific example where a message is to be relayed from the control station 2 via three relay elements 10b, 10c, 10d to a sensor unit 6e along the paths 316, 318, 320, 322; this message communication is illustrated in Figures 6 and 7, namely:

(1) the control station 2 assembles a message such that the relay element 10a is the first element in a predetermined path 314 and then transmits the message. The relay element 10a is, in this example, inactive and unable to respond to the message. The control station 2 being unable to detect a retransmission of the message from the relay element 10a assumes that the element 10a is not available for conveying the message. The control station 2 then modifies the assembled message so that the relay element 10b is selected instead of the element 10a and retransmits the message;

(2) the message is subsequently received and decoded at the relay element 10b which recognises its own address contained in the message. The element 10b error checks the message and disables its own address reference in the message before retransmitting the message;

(3) the message is subsequently received and decoded at the relay element 10c which recognises its own address contained in the message. The element 10c then error checks the message and disables its own address reference in the message before retransmitting the message;

(4) the message is subsequently received and decoded at the relay element 10d which recognises its own address contained in the message. The element 10d then error checks the message and recognises that the message is intended for a sensor unit 6e. The message is then

reformatted by the element 10d to suit the sensor unit 6e and subsequently retransmitted;

(5) the sensor unit 6e receives the message, decodes it and then either transmits an echo back signal as described previously, or transmits an acknowledgement message addressed to the relay element 10d, or both;

(6) the relay element 10d receives the acknowledgement message or the echo back signal from the sensor unit 6e and prepares a report message which is conveyed back via the relay elements 10c, 10b to the control station 2. The report confirms successful receipt of a message at its specified destination and makes reference to the time and validation data contained within the message for the sensor unit 6e.

If the relay element 10c is unable to convey the message to the relay element 10d in the example described above, the element 10b prepares a report message which it transmits back to the control station 2; this report indicates an unsuccessful communication to the relay element 10c and makes reference to the time and validation data within the message intended for the sensor unit 6e. Likewise, if the relay element 10d is unable to convey the message to the sensor unit 6e, the relay element 10d prepares a report message which is conveyed via the relay elements 10c, 10b to the control station 2; this report indicates unsuccessful communication to the sensor unit 6e and makes reference to the time and validation data of the message intended for the sensor unit 6e. When the control station 2 receives a report message indicating an unsuccessful receipt of a message, the control station 2 can either select an alternative route through the network 8 or, alternatively, abandon the communication task if the network connectivity is unacceptably poor.

An advantage of sending messages via a predetermined route selected at the control station 2, is that the station 2 is able to allocate communication activity between the relay elements 10 in order to distribute data flow loading on the network 8 and, as a

result, maintain a similar power drain from each internal power source 144 incorporated into the relay elements 10.

In some situations, information available at the control station 2 will not be sufficient for a user of the system 1 to be certain about the availability of a predetermined network route along which a message may reliably be sent, for example to an intended destination such as one of the sensor units 6. In order to cope with this situation, there is an autorouteing mode of operation where each relay element 10 in valid receipt of a message is allowed to seek an optimum path by which to send the message to the destination address specified in the message. In this mode of operation, an outgoing message contains a message source address, a message destination address, a current message address, time and validation data together with the message data; the source address is needed for reference when compiling a corresponding report message when the outgoing message has been received at the destination address, the destination address is needed to establish the location to which the message is intended, the current address is updated as the message propagates through the network 8, and time and validation data is needed for recognising the message and determining the time at which the message was originally transmitted.

The relay elements 10 are configured in this autorouteing mode of operation so that the control station 2 is permitted to attempt to transmit to any of the relay elements 10 in order to start a message transfer. Such operation confers a benefit that if the transmitter 18 is sufficiently powerful, the antenna 20 has sufficient gain and the effects of any radio shadows and interference are insignificant, the control station 2 is able to communicate directly to more remote relay elements in a skip mode of operation; this mode of operation avoids the time delay associated with a message being transferred from any relay elements in closer proximity to the control station 2 and thus has the effect of generally reducing the time needed for a message to propagate to a preferred relay element or sensor unit location.

A message transfer in the autorouteing mode entails the steps:

(1) the control station 2 selects the first relay element 10a and tests whether or not it will form an adequate communication path by transmitting to it. If the station 2 is unable to detect a responsive transmission from the element 10a, the station 2 assumes that this element is not available and selects a second relay element 10b and repeats the procedure;

(2) if the second relay element 10b is available, it decodes the message from the control station 2 and determines the intended message destination, namely the sensor unit 6e in Figure 7. With this information, the element 10b calculates the distance from itself to the intended destination specified in the message, and the approximate distance from its relay-element neighbours to the final destination by application of the Pythagorean theorem. The element 10b decides amongst a selection of feasible routes that the optimum route to the sensor unit 6e is via the elements 10c and 10d, and proceeds to transmit the message to the element 10c which, in turn, transmits to the element 10d;

(3) the message is subsequently received and decoded at the relay element 10d. Because the message is intended for a sensor unit 6e, it is reformatted into a format acceptable to the sensor unit 6e. If the sensor unit 6e fails to respond to the message, the element 10d can make an attempt to program the sensor unit 6e into a receive mode before eventually commencing, if unsuccessful in programming the sensor unit 6e, a blind alley routine which will be explained later;

(4) a similar strategy to that described in (1)-(2) above is adopted when passing information backwards through the system 1 from the sensor unit 6e to the control station 2, namely a report message is generated which contains information concerning the successful communication of the message to the sensor unit 6e.

In the message autorouteing operation described above, it is not permitted for a relay element to transmit back to a relay element which has previously handled the message in question, otherwise the message could circulate endlessly in the network 8 and thereby cause unnecessary power consumption in the transceivers 142 of the relay elements affected; such endlessly circulating messages are avoided by inhibiting the previous relay element from responding twice to a message which has an identical validation code contained within the message compared to a previously conveyed message passing through that previous relay element; this inhibition is achieved by each computer data-processing unit 140 in question storing in its memory details of the messages that have been conveyed through it. Thus:

(a) for this one exception, if a given relay element is unable to obtain a response from any of its neighbouring relay elements, then the element in question is permitted to initiate a blind alley recovery routine, which enables the element in question to communicate back to the preceding element, or to the control station 2 if the element in question is the first in a communication path through the network 8;

(b) if the network 8 connectivity is really poor, a message will be timed out by all relay elements 8 and by the control station 2 so that network 8 transmission capacity does not become overloaded with unreceived circulating messages; this timing out is achieved by comparing time data of the message with current system time.

A special route test message may be transmitted through the network 8 in order to establish integrity of the network 8. The address data contained in this route test message is similar to that of data and configuration messages as described above. However, the data field in the message that is used for sensor unit programming or data transfer is used in the case of a route test message to inform the control station 2 about those relay elements which are employed in routing the message to its specified destination and back to the station 2; as the route test message propagates through each relay element 10, the address reference of the relay element in question is added to the route test message. At the specified destination location for

the message, a corresponding report message is assembled for transmission back to the control station 2. When the report message eventually reaches the station 2, the report message contains the address references of all the relay elements that have handled the report message and the associated route test message.

The data processing units 14, 42, 140 are of identical design and housed so that they may be attached to a variety of proprietary transceivers; the use of FSK modulation of digital information in the modem 28, 128, 228 ensures compatibility of the data processing units 14, 42, 140 with any proprietary transceivers capable of supporting analogue voice communication where analogue signals in the frequency range of approximately 300 Hz to 3 kHz are to be accommodated.

In certain situations of system 1 deployment where unattended operation is required over an extended period, it is advantageous that power is not being constantly expended in the sensor units 6 and the relay elements 10 in order to conserve the electrical charge in the internal power sources 40,144; this power saving is achieved by operating the relay elements 10 and sensor units 6 in an intermittent transmission mode, referred to as burst mode, which also assists to reduce any opportunity of third parties eavesdropping on messages conveyed by the network 8 to the sensor units 6. Such power conservation resulting from burst mode operation is facilitated by incorporating the power controller 126, 226 which is itself controlled by the digital processor 130, 230 in the data processing units 42,140 of the relay elements 10 and sensor units 6.

Moreover, the radio channel selector 32, 132, 232 contained in each relay element 10, sensor unit 6 and the control station 2 enables the radio communication frequency employed for the communication of messages to be periodically altered, in a manner referred to as frequency hopping, by multiples of 25 kHz frequency spacings at a rate of 2 frequency hops per minute to ensure resilience against any fixed frequency radio interference affecting the system 1 and to assist in avoiding any eavesdropping by third parties; the clock 34,134,134 ensures that the timing of frequency hops is synchronised throughout the system 1. The data processing units 14, 42, 140 also perform error correction and encryption, or de-encryption, of data

contained in a received message before either conveying or acting upon the information contained within the message.

The circuit operation of the data processing unit 14,42,140 will now be described with reference to Figure 8. The terminal T2 links a source of electrical power, nominally 24 volts d.c., such as the battery 40, 144 to the power supply circuit 414 and the relay 410. The power supply circuit 414 regulates applied electrical power at a terminal Vcc for providing a stable regulated supply voltage to the clock oscillator 404, thereby assisting to ensure greater clock frequency stability. A control signal provided by the microcontroller 400 at the connection P29 controls switch contacts in the relay 410 for connecting or disconnecting terminals T1 and T2; this enables the microcontroller 400 to disconnect power from the transceiver 12, 38, 142 when it is operating in an inactive quiescent mode where neither reception nor transmission of signals from the transceiver 12, 38, 142 are required, thereby conserving energy in the source of electrical power. The clock oscillator output, namely CK O/P, provides a substantially frequency stable signal which is applied to the input, namely CK I/P, of the divider chain 406. The chain 406 comprises a series of binary counters whose outputs 420 are conveyed to the microprocessor 400 for providing time information. The buffer 408 provides an interface for RS232 communication where the terminals T8 and T9 function as RS232 outputs and the terminals T10 and T11 function as RS232 inputs. The components R1, D1 and ZD1 limit excessive input signal amplitude applied at the terminal T10 being conveyed to the connection 2A3 of the buffer 408 to a range -0.5 volts to +5 volts relative to a ground potential in the data processing unit 14, 42, 140. Similarly, the components R2, D2 and ZD2 limit excessive input signal amplitude applied at the terminal T11 being conveyed to the connection 1A2 of the buffer 408. The buffer 408 provides an impedance match to the connections P20, P24, RXD, TXD of the microcontroller 400 as well as adequate current sink/source capability to drive peripheral devices such as the interface 16. The relay 412 is responsive to signals provided by the microcontroller 400 at the connection P25 for enabling or disabling the transmitter 18, 118, 218 of the transceiver 12, 38, 142 in order to minimise power consumption during periods when signal transmission from the transceiver 12, 38, 142 is not required but when the transceiver 12, 38, 142 is in an inactive listening mode. The 8-bit data bus 416 connecting from the microcontroller 400 to the terminal

T5 is used for conveying signals relating to transceiver channel selection and other digital input/output control data for the transceiver 12,38,142. The capacitor C1 protects an input RX-i/p of the FSK modem 402 from excessive d.c. offsets which may disrupt the operation of the modem 402. The variable potentiometer VR1 provides adjustable attenuation of a FSK signal provided by the modem 402 at its connection TX-signal in order to ensure compatibility with the transceiver 12,38,142.

In one application of the invention, the sensor units 6 may be small portable devices to be worn by personnel working in hazardous environments, for example in a fire-fighting role, so that additional assistance can be brought into those areas where especial difficulty is experienced or personnel need to be rescued because environmental conditions become too severe. Moreover, the relay elements 10 may be small devices which are placed by personnel in suitable locations as they enter and move around in the hazardous environment. Such a data link system is particularly valuable in steel framed buildings where radio shadows may be experienced, where the sensor units are being constantly relocated, and where relay elements 10 become damaged or destroyed.

The sensor units 6 may also be employed to operate traffic lights and sense movement of traffic in the vicinity of the lights; the sensor units 6 communicate traffic conditions to the control station 2, where overall decisions regarding control of the traffic flow are made, as well as receiving instructions from the control station 2 regarding when to change the colour of the lights. Such use of the data link system in traffic flow control applications has the advantage that infrastructure required for installing the traffic lights is potentially much simplified, and hence less expensive. Moreover, radio attenuation effects of tall urban buildings and interference arising, for example, from vehicle ignition systems may be avoided by appropriate message routeing in the network 8.

The sensor units 6 and the relay elements 10 may alternatively be airborne; an example of this is remote airborne pilotless vehicles (RPVs) for reconnaissance or surveillance purposes. Alternatively, the sensor units 6 and relay elements 10 may be submerged in the form of an under water data link system utilising ultrasonic,

namely sonar, communication for use in undersea oil exploration and oil platform monitoring applications.

CLAIMS

1. A data link system comprising transmitting means, relaying means and receiving means responsive to signal reception by output of an acknowledgement signal, the transmitting means being arranged to route signals either directly to the receiving means or indirectly thereto via the relaying means in accordance with whether or not an acknowledgement signal is generated thereby.

2. A data link system according to Claim 1 wherein the relaying means comprises a plurality of relay elements.

3. A data link system according to Claim 2 wherein the relay elements are operative to seek successive signal propagation routes to the receiving means until an acknowledgement signal is generated thereat.

4. A data link system according to Claim 2 or 3 in which the relay elements are selectable from the transmitting means so that signal data flow is configurable to improve uniformity of data flow allocation between the relay elements.

5. A data link system according to any preceding claim wherein the receiving means outputs an acknowledgement signal at a predetermined time after valid signal reception thereat.

6. A data link system according to any preceding claim wherein signal propagation within the system is arranged to be terminated after a set time period from initial output of the signal from the transmitting means.

7. A data link system according to any preceding claim wherein the system is arranged to convey periodically a message signal within the system for determining availability of the system for supporting communication.

8. A data link system according to any preceding claim wherein the transmitting means, the relaying means and the receiving means each incorporate a data processing unit including power control means, FSK demodulating-modulating means, communication-frequency selecting means, a clock, digital processing means and interface multiplexing means.

9. A data link system according to Claim 8 wherein the interface multiplexing means is a RS232 multiplexer.

10. A data link system according to Claim 8 or 9 wherein the communication-frequency selecting means is operative to alter periodically transmission frequency of signals propagating from the transmitting means, the relaying means and the receiving means.

11. A data link system according to any preceding claim wherein the transmitting means, relaying means and receiving means are arranged to be switchable between inactive and active states in which they are arranged to transmit and receive signals in the active state whereas they are arranged only to receive signals in the inactive state at reduced power requirement relative to the active state.

12. A data link system according to any preceding claim wherein the relaying means, receiving means and transmitting means are arranged to apply error correction to signals conveyed thereto.

13. A data link system according to any preceding claim wherein transmitting means, relaying means and receiving means are arranged to encrypt or de-encrypt signals conveyed thereto.

14. A data link system according to any preceding claim wherein a part of the relaying or receiving means is arranged to be addressable by an individual address unique to that part, by a group address unique to that part and other

parts of the relaying and receiving means, and by a general address which is common to the entire relaying and receiving means.

15. A data link system according to Claim 14 wherein the group address is arranged to be reconfigurable to address different parts of the relaying and receiving means.

16. A data link system according to any preceding claim wherein the receiving means incorporates sensing means.

17. A data link system according to any preceding claim wherein the relaying and receiving means incorporate local power supply means or local power generation means.

18. A data link system according to any preceding claim wherein the system is operative to control traffic flow.

19. A data link system according to any preceding claim wherein the relaying means, transmitting means and receiving means are arranged to be personnel-wearable.

20. A data link system according to any preceding claim wherein the transmitting means, relaying means and receiving means incorporate microcontrollers for managing message communication.

21. A method of communication in a data link system incorporating a transmitting means, receiving means and a plurality of relay elements, the method including the steps of :-

(a) transmitting a message signal to the receiving means;

(b) awaiting an acknowledgement signal from the receiving means;

(c) in the absence of an acknowledgement signal within a predetermined time period, selecting an alternative signal route via the relay elements for transmitting the message signal to the receiving means, transmitting the message signal, and awaiting an acknowledgement signal from the receiving means via the relay elements;

(d) repeating step (c) until an acknowledgement signal is received.

22. A method of communication in a data link system according to Claim 21 in which in step (c) the message signal is permitted to propagate between relay elements for a predetermined time period only after it is radiated from the transmitting means.

23. A method of communication in a data link system according to Claims 21 or 24 in which in step (c) the signal route is selected at the relay elements instead of at the transmitting means.

24. A method of operating a data link system incorporating a transmitting means, receiving means and a plurality of relay elements, the method including the steps of:

(a) providing at least some of the receiving means and the relay elements with message modifying means for recordal of reception;

(b) transmitting a message signal containing information for routeing the message through the system;

(c) receiving and modifying the message signal at that or as the case may be those of the relay elements and receiving means;

(d) transmitting the modified message signal therefrom;

(e) repeating steps (b) and (c) as instructed in the message signal;

(f) receiving the modified message signal at the transmitting means and determining therefrom the interconnectivity of the relay elements and the receiving means which have conveyed the message in steps (c) to (e).

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25

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Claims searched: 1-25

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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): H4L (LDRR, LDFC) H4P (PEE)

Int Cl (Ed.6): H04B 7/14 7/145 7/15 7/155 7/165 7/17 7/24 7/26

Other: On-line: WPI, CLAIMS

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	US4882765 (Maxwell&Wright) whole document	1-2, 17, 21
X	JAPIO Abstract Accession No. 02948027 & JP010245627A (Matsushita) see abstract	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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